Chapter 6
Keynote Introduction: Biomass Technologies and Markets in Africa

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Abstract Globally, many different biomass technologies for energy production are available. They all have the same general common feedstock, namely biomass which is the organic matter derived from plants and animals, such as agricultural crops, forests, organic wastes, and animal waste. Biomass can be used for different purposes (feed, fibre, food, fuel) including energy production. Bioenergy is the final energy output derived from biomass/feedstock. This includes liquid, gaseous, and solid biofuels which are converted into heat, electricity, light, transportation energy (kinetic energy) and other energy types. In Africa, currently mainly traditional technologies for biomass conversion are used. This includes the use of wood-fuels for cooking. However, also modern technologies are increasingly important in Africa. The present chapter describes different technologies applied or suitable for African framework conditions. It furthermore provides an overview on the existing bioenergy markets in Africa.

Keywords Biofuel technologies • Markets • Value-chain • Feedstock • Process • Energy carrier • Energy service

6.1 Introduction

Globally, many different biomass technologies for energy production are available. They all have the same general common feedstock, namely biomass which is the organic matter derived from plants and animals, such as agricultural crops, forest, organic wastes, and animal waste. Biomass can be used for different purposes

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(feed, fibre, food, fuel) including energy production. Bioenergy is the final energy output derived from biomass/feedstock. This includes liquid, gaseous, and solid biofuels which are converted into heat, electricity, light, transportation energy (kinetic energy) and other energy types.

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6.2 Biomass Value Chains and Options in Africa

In order to assess and evaluate bioenergy technologies, the whole value chain of a bioenergy system has to be considered. Typical bioenergy value chains include biomass production, transport, conversion, and consumption. Along the value chain, different impacts can be measured, such as social, economic and environmental impacts. Value chains and their impacts are mainly influenced by the following four characteristics:

- Feedstock type (waste, lignocellulosic material, oily crops, sugar crops, starchy crops, dedicated energy crops, co-products)
- Conversion technology (biological, mechanical, thermal, chemical processes)
- Intermediate energy carrier type (solid, gaseous, liquid energy carrier)
- Energy service (electricity, transport, heat, cooking and lighting)

The options for bioenergy in Africa are manifold since the use of biomass is applicable at different scales, under various climatic conditions and under different framework conditions. Bioenergy options in Africa range from small-scale household applications (e.g. wood-fuels for cooking) to large-scale liquid biofuel production for transport. For all scales, different mechanical, thermo-chemical and biological conversion technologies are available.

Due to the potential of different bioenergy pathways to substitute other energy sources, bioenergy could be a solution to meet all types of energy needs: cooking, lighting, electricity, heat, and transport, depending on the feedstock and on the technology. Bioenergy options for biomass feedstock, technologies and energy needs in Africa are shown in Table 6.1.

Considering the different options listed in Table 6.1, the main criterion for sustainability is related to the feedstock production. Thereby waste material is usually a preferred feedstock source since it avoids land use and other sustainability conflicts, and since it contributes to sustainable waste management practices. Another main criterion to be considered is the efficiency of the systems. Inefficient systems need to be improved. For instance, many African households are still cooking with inefficient three-stone stoves. By improving the stove technology, considerable amounts of wood-fuel could be saved. Furthermore, a general challenge in Africa is

Table 6.1 Traditional and potential bioenergy options for biomass feedstock, technologies and energy needs in Africa

Feedstock	Processes	Energy carrier	Energy service
Non-renewable wood *(wood from land where trees/shrubs do not regrow)*	*Combustion in stoves*[a] *Conversion into charcoal*[a,b,c] *Gasification*[c] *Co-firing in medium-large combustion plants*[c]	*Firewood*[a,b,c] *Charcoal*[a,b,c]	*Cooking*[a] *Electricity*[b,c] *Process heat*[c]
Renewable wood (wood from sustainable managed forests)	Chipping[c,d] Pelletisation[c,d] Combustion in stoves[a] Conversion into charcoal[a,b,c] Gasification[c] Co-firing in medium-large combustion plants[c]	Woodchips[c,d] Pellets[c,d] Firewood[a,b,c] Charcoal[a,b,c] Syngas[c,d]	Cooking[a] Electricity[b,c] Process heat[c,d] Second gen. biofuels[d]
Oil crops (e.g. jatropha, castor, palm oil, ximenia)	Pressing[a,b,c,d] Transesterification for biodiesel production[c,d]	Straight vegetable oil[a,b] Biodiesel[c,d]	Cooking (SVO)[a] Electricity (SVO, BD)[b] Transport (SVO, BD)[c,d]
Waste oil (waste cooking oil, animal fat, fish oil)	Collection[b,c,d] Transesterification for biodiesel production[c,d]	Straight vegetable oil[a,b,d] Biodiesel[c,d]	Electricity (SVO, BD)[b,c] Transport (SVO, BD)[c,d]
Sugar and starch crops (e.g. sugarcane, sweet sorghum, cassava)	Fermentation and destillation[c,d] Geling[c]	Bioethanol[c,d] Ethanol gelfuel[c]	Transport (ethanol)[c,d] Cooking (ethanol and gelfuel)[a]
Dedicated lignocellulosic energy crops (e.g. acacia, dichrostachys, prosopis, miscanthus, typha)	Chipping[c,d] Pelletisation[c,d] Gasification[c,d] Hydrolysis, fermentation, distillation[d] Torrefaction[d]	Woodchips[c,d] Pellets[c,d] Charcoal[c,d] Syngas[c,d] Pyrolysis oil[c,d] Torrefied biomass[d]	Electricity[c,d] Process heat[c,d] Second gen. biofuels[d]
Manure *(manure collected from the field, manure from stables)*	*Dried manure combusted in stoves*[a] Wet manure for anaerobic digestion[a,b,c,d]	*Dried manure for cooking*[a] Biogas[a,b,c,d] Biomethane[c,d]	Cooking[a] Lighting[a] Electricity and heat[b,c] Biomethane in transport[d]
Dry industrial organic waste (e.g. nutshells, bagasse, rice husks)	Conversion into charcoal[c,d] Gasification[c,d] Hydrolysis, fermentation, distillation[d] Co-firing in medium-large combustion plants[c,d]	Dried waste material[c,d] Charcoal[c] Syngas[c,d] Ethanol[c,d] FT diesel[d]	Electricity[c,d] Process heat[c,d] Second gen. biofuels[d]

(continued)

Table 6.1 (continued)

Feedstock	Processes	Energy carrier	Energy service
Wet industrial organic waste (e.g. molasse, palm oil mill effluent – POME)	Fermentation and destillation[c,d] Geling[c] Anaerobic digestion[c,d]	Bioethanol[c,d] Biogas[c,d] Biomethane[d] Ethanol gelfuel[c]	Transport (ethanol)[c,d] Cooking (ethanol and gelfuel)[a] Electricity and heat[b,c] Biomethane in transport[d]
Organic solid household waste (organic waste collected from households)	Anaerobic digestion[c,d] Co-firing in medium-large combustion plants[c,d]	Biogas[c,d] Biomethane[d] Dried waste[c,d]	Electricity and heat from biogas[c,d] Biomethane in transport[d] *Electricity and heat from co-firing*[d]
Food waste (e.g. catering waste from restaurants, expired food from supermarkets, spoiled waste)	Anaerobic digestion[c,d]	Biogas[c,d] Biomethane[d]	Electricity and heat[c,d] Biomethane in transport[d]
Sewage sludge (from wastewater treatment plants)	Anaerobic digestion[c,d]	Biogas[c,d] Biomethane[d]	Electricity and heat[c,d] Biomethane in transport[d]

SVO: straight vegetable oil, BD: biodiesel
Italic: This option should be phased out as soon as possible
[a] Application at household level
[b] Application at village level
[c] Application at medium enterprise level
[d] Application at industrial level

the efficiency of the agricultural sector, independently if bioenergy or other uses of agricultural crops are considered.

6.3 Overview of Energetic Biomass Use in Africa

As it is shown in Table 6.1, the value chains are highly influenced by the energy carriers (e.g. charcoal, pellets, biogas, biofuels) which shall be produced. The energy carrier influences the feedstock selection, the conversion technology and the final energy service. Therefore, the following overview of the energetic biomass use in Africa is presented for a variety of different energy carriers.

6.3.1 Charcoal and Firewood

Wood based fuels or so called wood-fuels include firewood and charcoal. In Sub-Saharan Africa, wood-fuels provide more than 70% of the total energy consumption. The majority of the population depends on wood-fuels because modern energy such as LPG, kerosene and electricity are either unavailable or unaffordable (Legros et al. 2009).

Firewood for cooking is mainly used in rural areas whereas charcoal is mainly used in urban areas. For instance in Tanzania, more than 80% of the urban population depends on charcoal for their daily cooking (Sawe 2009). Charcoal in urban areas is preferred to firewood mainly since it has a higher calorific value per unit weight and thus can be transported more efficiently over longer distances. Furthermore, it needs less storage room, is more stable to store, and cleaner in combustion.

Wood-fuels are used by many African people since they are cheap, available and easy to handle. Thus, they constitute an important energy source for Africa. However, major problems associated with the use of wood-fuels are deforestation, and forest degradation, as well as health and safety issues when used as cooking fuel.

In comparison to the rather simple value chain of firewood production and use, the value chain for charcoal is larger and more complex, comprising a wide range of actors and operators with varying interests and stakes (Vos and Vis 2010).

Charcoal is produced from biomass (usually wood) by the carbonisation process (slow pyrolysis) which is the conversion of biomass in absence of air, under high temperatures and with long reaction times. This is typically done in batches of 1–5 tons in earth, brick or steel kilns. In Africa charcoal production is often illegal and unregulated causing deforestation at large-scale.

6.3.2 Agricultural and Forestry Residues

One of the current success stories of modern bioenergy implementation in Africa is the use of agricultural residues (bagasse) from the sugar sector in Mauritius for the production of electricity and process heat. Bagasse based co-generation is common practice in the Sub-Saharan sugar industry since many years, however Mauritius was the first country in Sub-Saharan Africa to promote the use of highly efficient high pressure co-generation equipment to increase the production of modern bioenergy. Since the 1990s bagasse based electricity is exported to the national grid. In 2004 the installed co-generation capacity in the Mauritian sugar sector was 242 MW with 318 GWh (16.5% of the electricity consumption in Mauritius) produced from bagasse and 407 GWh (21.2%) produced from coal (Deepchand 2005). Today, the sugar industry in Mauritius is self sufficient in energy and contributing about 50% of the national electricity supply through electricity exports to the grid (Karekezi and Kimani 2010). Co-generation in Mauritius is using bagasse during the harvest season (about 6 months) and coal during the rest of the year.

The development of bagasse based co-generation was strongly supported by the government of Mauritius (Karakezi et al. 2008). In 1985, the Sugar Sector Package Deal Act was enacted to encourage the production of bagasse for the generation of electricity. The Sugar Industry Efficiency Act (1988) provided tax incentives for investments in the generation of electricity and encouraged small farmers to provide bagasse for electricity generation. Together with the Bagasse Energy Development Programme (BEDP) of 1991 and the abolishment of sugar export duties in 1994, these measures resulted in a steady growth of bagasse-based electricity production in Mauritius.

In addition to the political support another important prerequisite for the success of the sugar cane bagasse based co-generation programme in Mauritius is its effective revenue sharing measures. Thereby, it is guaranteed that the monetary benefits from the sales of electricity are shared between all stakeholders of the sugar value chain including the poor smallholder sugar cane farmers.

In recent years several Sub-Saharan African countries have implemented initiatives to follow the Mauritian success story in the use of agricultural residues for energy production. In 2007 the regional initiative 'Cogen for Africa' (http://cogen.unep.org), funded by the Global Environmental Facility (GEF), was launched in order to significantly scale up the use of efficient cogeneration systems initially in seven Eastern and Southern African countries (Kenya, Ethiopia, Malawi, Sudan, Uganda, Tanzania and Swaziland). Agro-industries that are actively participating in the project include private-sector-owned sugar companies as well as private sector entities involved in agro-processing industries such as pulp and paper, forest products, palm oil, ground nuts, sisal and rice.

By February 2011, more than 100 investment opportunities for co-generation projects based on agricultural residues have been identified by 'Cogen for Africa'. Furthermore, it is estimated based on current sugar production in Sub-Saharan Africa that bagasse based cogeneration from sugar industries can meet about 5% of the total electricity demand in the region (Karekezi and Kimani 2010). Including the residues of other agro-industries and forestry industries about 10% of the electricity could be generated through co-generation.

Finally, one of the main advantages making co-generation from agricultural and forestry residues a promising option for modern bioenergy production in Sub-Saharan Africa is the fact that well established agro-industries and forestry industries have available financial resources in order to implement efficient bioenergy technologies in the short term. Private investment in bioenergy technologies, however, needs appropriate and supportive legal and regulatory frameworks in place providing suitable incentives as well as economically viable access to electricity grids (including reasonable feed-in tariff structures).

6.3.3 Torrefied Biomass

Torrefaction is a thermo-chemical treatment of biomass between 200 and 340°C. Thereby biomass is partly decomposed releasing volatile compounds. Torrefied biomass has approximately 30% more energy content per unit of mass than the biomass feedstock used. Currently, the interest in the use of torrefied biomass especially in large co-combustion power plants is increasing amongst European and North American stakeholders. In Africa, torrefaction could be a suitable technology, but is not yet applied.

6.3.4 Briquettes, Pellets, and Woodchips

Besides wood-fuels and torrefied biomass, solid biofuels include briquettes, pellets and woodchips. The production and use of these fuels in Africa is still very limited.

Biomass briquettes are blocks or balls of compacted small biomass particles. Common briquettes are charcoal and biomass briquettes made from sawdust, carbonised sawdust or waste materials (e.g. charcoal residues, sunflower shells, paper). There are various ways of producing briquettes including mechanical treatment (pressure) and mixing different substances (e.g. waxes, water). The latter technology is promoted mainly for small-scale applications in various development projects. Depending on the process and the input material, the quality of briquettes varies largely. The quality influences the use of the briquettes which can be either used at small-scale (for cooking) or at industrial-scale for large co-combustion facilities.

Pellets are generally made from compacted sawdust or other biomass (e.g. straw) that was grinded e.g. in a hammer mill. The pelletizing process is rather industrialised. Pellets are very energy dense with low humidity. Due to their often standardised nature (quality standards exist e.g. in Europe) in size and quality, pellets can be easily traded and marketed. There is an increasing market for pellets in Europe and North America to be used in biomass heating systems at household to medium-size level. In Africa, pellets are currently not used and produced at large-scale. However, due to their characteristics, pellets produced in Africa could be easily exported to international markets (e.g. Europe).

Woodchips are small pieces of wood resulting from cutting or chipping trees, branches, and other woody material. Woodchips can be used to produce heat and electricity. Although the potential for woodchips in Africa is considerable, the use of woodchips is not yet widely applied.

6.3.5 Biogas and Biomethane

Biogas is produced by anaerobic digestion (AD) which is a microbiological process of decomposition of organic matter (manure, sewage sludge, wet organic waste, energy crops) by microorganisms in the absence of oxygen (Al Seadi et al. 2008). AD is common to many natural environments and largely applied today to produce biogas in airproof reactor tanks and covered lagoons commonly named digesters. Technologies range in scale from domestic systems for thermal (cooking) energy to multi-megawatt grid-connected combined heat and power generation systems, or even systems that inject biomethane (upgraded biogas to $<95\%$ CH_4 content) into natural gas grids.

A wide range of micro-organisms are involved in the anaerobic process which has two main end products: biogas and digestate. Biogas is a combustible gas consisting of methane, carbon dioxide and small amounts of other gases and trace elements.

The methane fraction of biogas can be burned to produce light, electricity and heat. Digestate is the decomposed substrate, rich in macro- and micro nutrients and therefore suitable to be used as fertiliser.

In several countries in Europe there is currently a boom in agricultural medium sized biogas plants with an average electrical plant capacity of about 400 kW. Currently, in Germany alone, more than 6,000 biogas plants are in operation.

Also in Africa the numbers of biogas installations is increasing, especially for small-scale domestic biogas plants supplying households with energy for lighting and cooking (Austin and Morris 2011). A number of national domestic biogas programmes were set up in Africa each with national targets of over 10,000 domestic systems to be installed in the next 5 years. National programmes in Africa are currently implemented in Rwanda, Tanzania, Kenya, Uganda, Ethiopia, Cameroon, Benin and Burkina Faso (SNV 2010).

One of the main advantages of medium to large-scale biogas production is the potential to use wet organic waste materials which are converted to biogas and digestate which can be used as fertiliser. This presents on the one hand large opportunities for Africa, but on the other hand, this depends on the introduction of suitable waste management practices and logistics.

6.3.6 Pure Plant Oil and Biodiesel

A large portion of liquid biofuels can be received from lipid sources such as plant, animal and waste oils (Rutz and Janssen 2008). There exist mainly two types of fuels that are based on lipids: pure plant oil (PPO) and biodiesel obtained from further processing PPO.

Feedstock material in Africa is diverse and includes for example jatropha, palm oil, soy, castor, sunflower, coconut, and many other crops (Walimwipi et al. 2011). Also waste cooking oil and animal fats from the rendering or fish industry could be potentially used. In the PPO and biodiesel value chain, the feedstock selection highly affects the quality and the properties of the fuel which influences the potential use. PPO and biodiesel for transport applications must meet high quality standards in order to ensure smooth engine operations. Several African countries have started to introduce national targets and initiatives for the use of biofuels (both biodiesel and bioethanol) in transport, including for example Angola, Benin, Ethiopia, Ghana, Kenya, Madagascar, Malawi, Mali, Namibia, Nigeria, Senegal, South Africa, Swaziland, Tanzania, Zambia, and Zimbabwe (Walimwipi et al. 2011; Janssen and Rutz 2011).

However, many approaches in Africa do not target the use of PPO and biodiesel in transport, but in small-scale stationary power stations for rural electrification. Often, these projects include multifunctional platforms (MFP) for different services. Small-scale projects usually use pure plant oil directly, whereas large-scale projects aim at further processing of the oil into biodiesel.

Technologies for the pressing, purification and transesterification processes are mature and available for different sizes and purposes. Biodiesel production can range from small-scale, often batch-production, to large-scale industrial facilities.

For example in South Africa, several micro- to small-scale biodiesel plants are operated by small fleet owners or home producers using waste oils.

A relatively new approach is to produce biodiesel from algae at industrial scale. However, technologies are not yet mature and it is unclear if the algae to biodiesel chain will be commercial in the mid- to long-term. It may be also possible that oils from algae are rather used for chemical purposes instead of bioenergy due to their high production prices. Several areas in Africa may be suitable for the production of algae.

6.3.7 Bioethanol

The use of bioethanol in the energy sector is widely applied today. The main producers of bioethanol are the USA and Brazil and bioethanol is traded internationally. It is mainly produced by fermentation of sugar and starch. Bioethanol can be produced at different scales; however, most facilities are large-scale.

The main feedstock today are sugarcane, sugar beets, corn, and wheat. In Africa, the main feedstock is sugarcane, but in recent years much research was put on breeding sweet sorghum varieties for bioethanol production (Munyinda et al. 2011; Chagwiza and Fraser 2011; Janssen et al. 2010). The advantage of sweet sorghum is its higher production efficiency compared to sugarcane and its tolerance to difficult growth conditions (e.g. drought, soil acidity). Other potential feedstock sources in Africa are grain sorghum, cassava, and maize. Also molasses from the sugar industry can be used for bioethanol production.

In recent years, many efforts were placed on the production of ethanol from lignocellulosic biomass, so called second generation bioethanol. It is estimated that the technology of second generation bioethanol production is close to commercialisation. Besides waste materials (e.g. bagasse), potential second generation feedstock in Africa could be miscanthus and bamboo (Munyinda et al. 2011).

Munyinda et al. (2011) estimated the bioethanol potential in selected African countries for different feedstocks at 35 EJ, with the Democratic Republic of Congo having the largest potential, followed by Angola, Sudan, Zambia and Tanzania. Bioethanol production in Africa was 637 million l in 2007, with the largest production in South Africa, followed by Egypt and Nigeria.

A number of African countries have introduced initiatives and targets to promote bioethanol development for transport, including Ethiopia, Kenya, Malawi, Nigeria, South Africa, Sudan, and Zimbabwe. A niche market exists for the use of liquid ethanol and ethanol-gel for domestic use in cooking facilities.

6.3.8 Pyrolysis Oil, Syngas and Other Thermo-Chemical Conversion Products

Lignocellulosic biomass can be converted by thermo-chemical processes into various valuable intermediate products, including syngas, pyrolysis oil, char, and slurry (mixture of char and pyrolysis oil). The desired product is influenced by the reactor design and several parameters, such as the temperature, reaction time, reaction agent, and pressure. Suitable feedstock are all types of dry lignocellulosic materials such as waste materials (e.g. rice husks, nutshells, straw) and dedicated energy crops such as short rotation shrubs and trees as well as grasses. Potential feedstock in Africa would be acacia, eucalyptus, miscanthus, bamboo, or typha.

Some of the above mentioned intermediate products can be directly converted into energy. For instance, syngas can be used in gas engines and pyrolysis oil in diesel engines to produce electricity. Some pyrolysis plants for electricity production are e.g. installed in West Africa (Novis 2010). Pyrolysis oil, char and slurry can be also gasified in order to obtain syngas.

Syngas, either obtained by direct gasification of biomass or by gasification of pyrolysis oil, char and slurry, can be further processed by e.g. Fischer-Tropsch synthesis to produce Biomass-to-Liquid (BtL) fuels for transport. South Africa has large experience in synthesising syngas from coal and natural gas. However, BtL fuels are not yet produced at commercial scale and it will need several years to make BtL fuels competitive to fossil fuels and other biofuels.

6.4 Conclusion

As in many developing countries, bioenergy in Africa is currently mainly based on traditional use of bioenergy (i.e. wood-fuels used for cooking in simple stoves). Several initiatives in Africa are also promoting the modern conversion of biomass into high value solid, liquid and gaseous energy carriers, but the current market is still comparably small. Currently, the main progress in modern conversion of biomass is achieved in Europe, North America and some countries in Latin America and Asia.

An important challenge is to promote knowledge, technology and experience transfer on modern bioenergy to African countries. Furthermore, the cooperation between African countries has to be encouraged to develop suitable strategies for different technologies and adequate policies. Finally, also experience transfer from African countries to other continents should be supported. For instance the large experience in South Africa in synthesis of syngas could contribute to support the faster commercialisation of BtL fuels. Furthermore, the understanding of local framework conditions and circumstances (climate, policies, soil properties, social aspects) in Africa has to be transferred to foreign investors and technology providers for the successful creation of modern bioenergy markets in Africa.

References

Al Seadi T, Rutz D, Prassl H, Köttner M, Finsterwalder T, Volk S, Janssen R (2008) Biogas handbook. BiG>East Project funded by the Europen Commission (EIE/07/214), University of Southern Denmark Esbjerg, Denmark, p 142, ISBN 978-87-992962-0-0

Austin G, Morris G (2011) Biogas production in Africa. In: Janssen R, Rutz D (eds.) Bioenergy for sustainable development. Springer Verlag, Germany

Chagwiza C, Fraser G (2011) Economic evaluation of sweet sorghum in biofuel production as a multi-purpose crop: the case of Zambia. In: Janssen R, Rutz D (eds.) Bioenergy for sustainable development. Springer Verlag, Germany

Deepchand K (2005) Sugar cane bagasse energy cogeneration – lessons from Mauritius. Paper presented to the parliamentarian forum on energy legislation and sustainable development, Cape Town, South Africa, 5–7 October 2005

Janssen R, Rutz D (2011) Keynote Introduction: overview on bioenergy policies in Africa. In: Janssen R, Rutz D (eds.) Bioenergy for sustainable development. Springer Verlag, Germany

Janssen R, Rutz D, Braconnier S, Reddy B, Rao S, Schaffert R, Parella R, Zaccharias A, Rettenmaier N, Reinhardt G, Monti A, Amaducci S, Marocco A, Snijman W, Terblanche H, Zavala-Garcia F (2010) Sweet sorghum – an alternative energy crop. In: Proceedings of the 18th European Biomass Conference and Exhibition, Lyon, France, 3–7 May 2010, pp 200–206, ISBN 978-88-89407-56-5

Karekezi S, Kimani J (2010) Bioenergy development in sub-Saharan Africa. In: Making It Magazine, 26 March 2010

Karakezi S, Kithyoma W, Muzee K, Oruta A (2008) Scaling up bioenergy in Africa. Presented during the international conference on renewable energy in Africa, Dakar, 16–18 April 2008

Legros G, Havet I, Bruce N, Bonjour S (2009) The energy access situation in developing countries: a review focussed on the least developed countries and sub-Saharan Africa. United Nations Development Programme (UNDP) and World Health Organization 2009

Munyinda K, Yamba FD, Walimwipi H (2011) Bioethanol potential and production in Africa: sweet sorghum as a complementary feedstock. In: Janssen R, Rutz D (eds.) Bioenergy for sustainable development. Springer Verlag, Germany

Novis (2010) http://www.novis.de/?lang_pref=en. Accessed 3 Apr 2011

Rutz D, Janssen R (2008) Biofuel technology handbook, 2nd edn. WIP Renewable Energies, München

Sawe EN (2009) Sustainable charcoal production for poverty reduction in Tanzania. Bioenergy for sustainable development in Africa conference in Brussels, Belgium, 24-25 November 2009. TaTEDO, http://www.compete-bioafrica.net/events/events2/Brussels/S4-3-COMPETE-Conference-Brussels-Nov2009-Sawe.pdf

SNV (2010) Domestic Biogas Newsletter. Issue 3, August 2010

Vos J, Vis M (2010) Making charcoal production in Sub-Sahara Africa sustainable. NL Agency, The Netherlands

Walimwipi H, Yamba FD, Wörgetter M, Rathbauer J (2011) Biodiesel production in Africa. In: Janssen R, Rutz D (eds.) Bioenergy for sustainable development. Springer Verlag, Germany